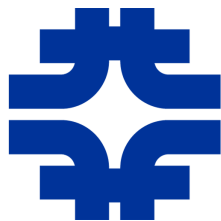


# MuCool Test Area Update



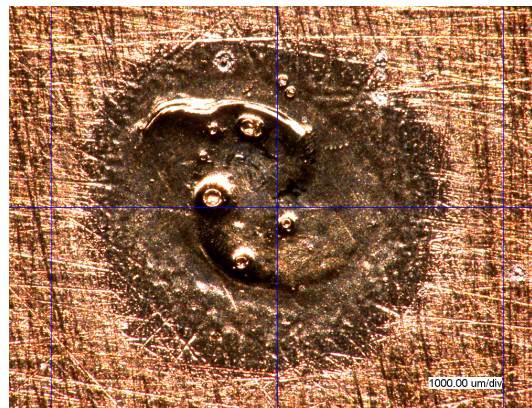
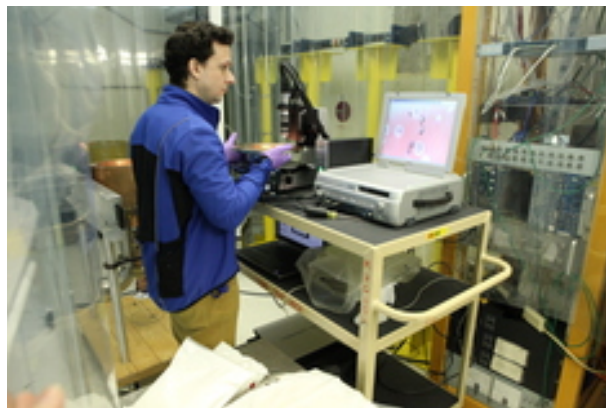
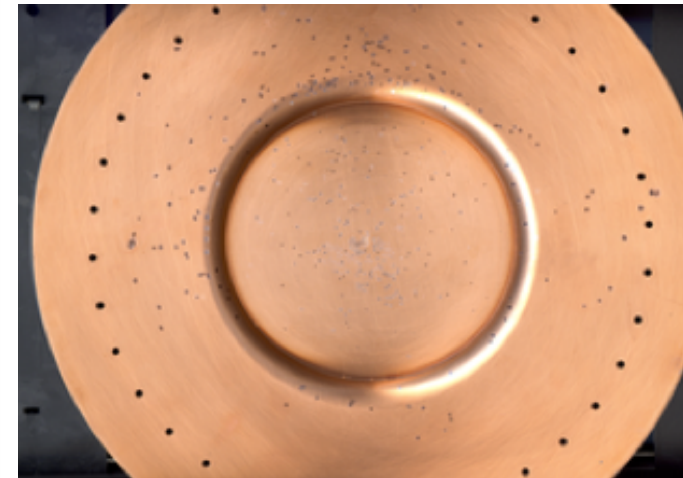
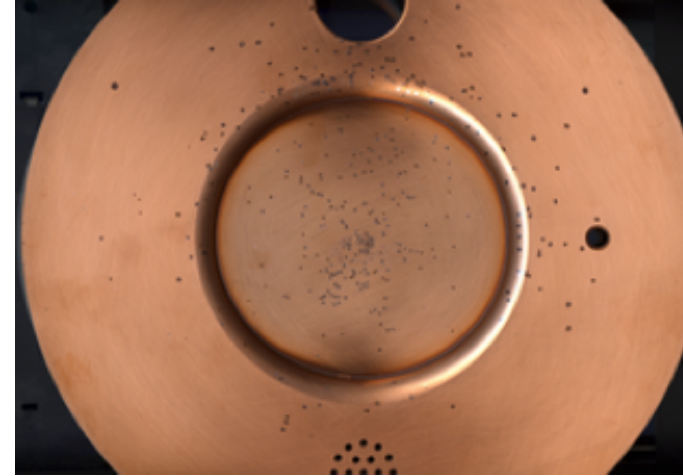
Yağmur Torun  
Illinois Institute of Technology



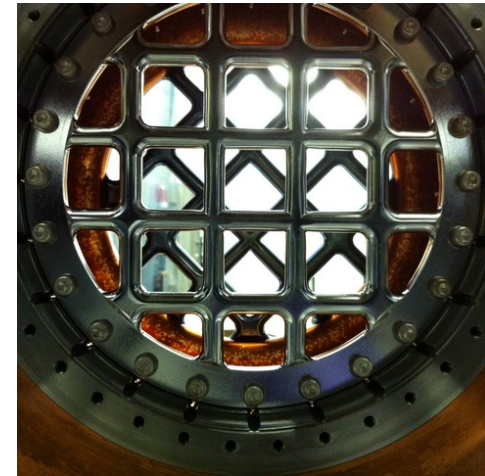
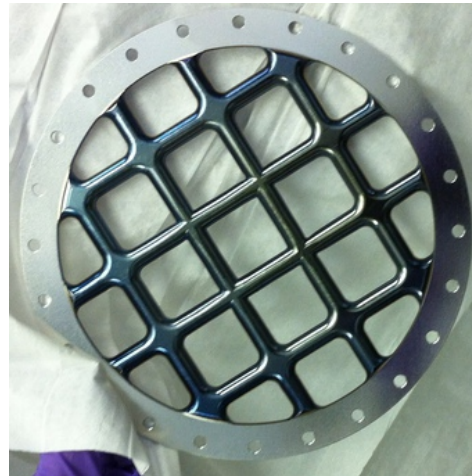
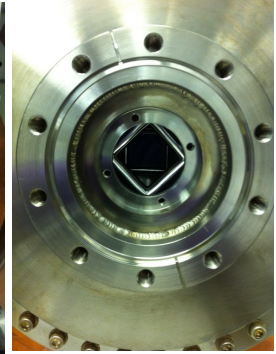
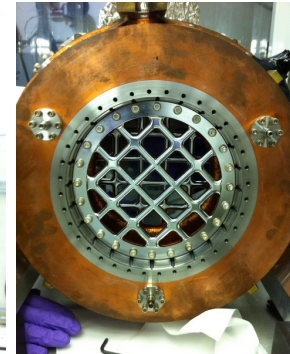
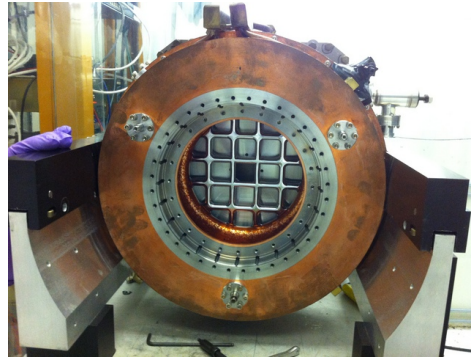
*All Experimenters' Meeting*  
*Fermilab – January 27, 2014*

- Advance **Technology Development** for ionization cooling
  - help design, prototype, test components
    - grid windows, modular pillbox, dielectric-loaded HPRF
- Inform machine **Design & Simulation** studies
  - provide performance envelope
    - vacuum RF in external magnetic field
    - HPRF in beam
- Support **Systems Demonstrations**
  - MICE
    - Single-Cavity Module assembly, instrumentation, testing

- Last run complete
  - 25 MV/m at B=0
  - 20-22 MV/m @ B=0.25-5T [preliminary]  
(sparking rate  $\leq 1$  in  $10^5$ )
  - cavity removed from MTA
- Inspection
  - similar spots on endplates
  - more around coupler
  - scanner & microscope tested
- Data analysis in progress
  - publication draft soon

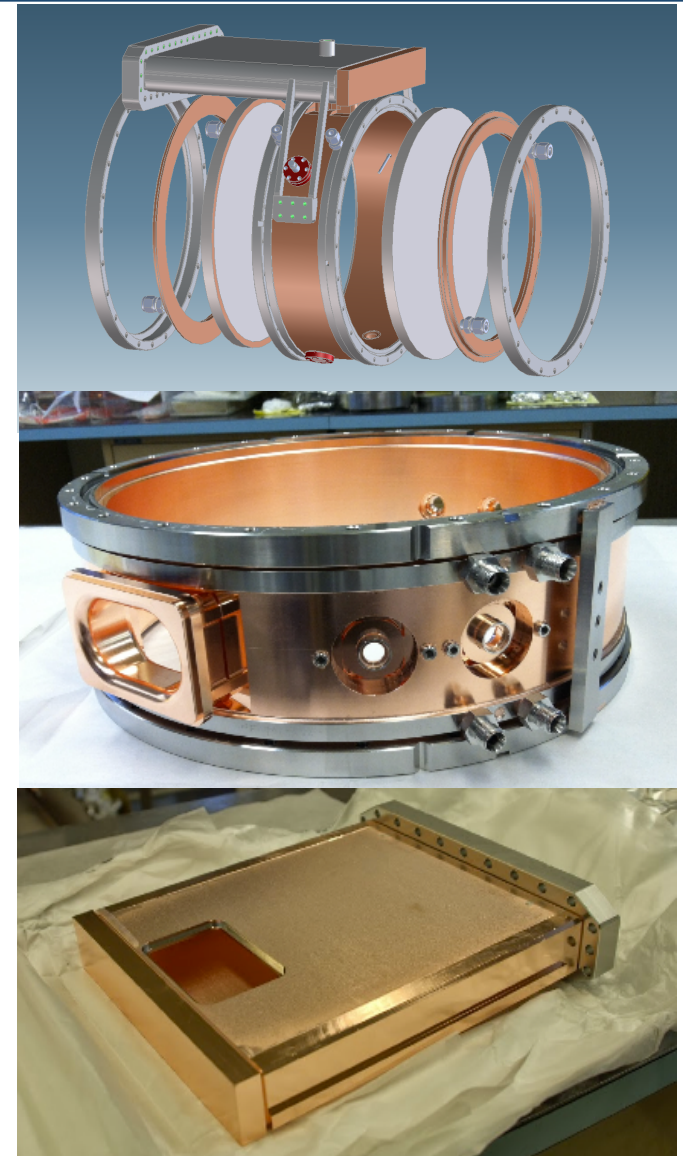


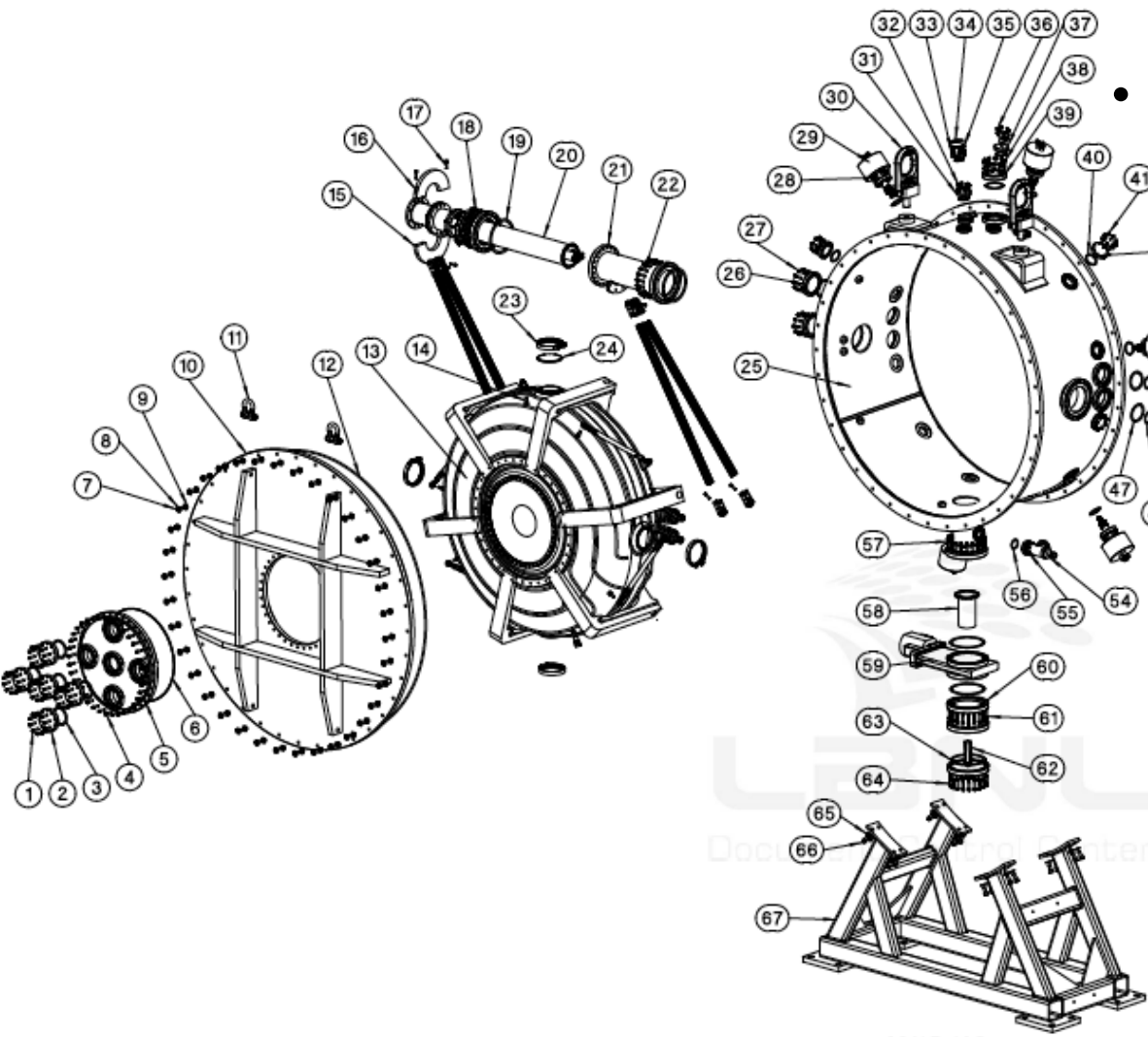
- Final test in progress
- Windows: low radiation length, good electrical and thermal conductivity
  - Flat thick Cu ✓
  - Thin pre-stressed flat Be ✗
  - Thin curved TiN/Be ✓
  - Exploring alternative: gridded tube windows
    - Solid Al prototype for test
    - Electro-polished
    - TiN coated (one face)
    - Cavity assembled with grids (and spacer), installed in solenoid – running now
  - M. Alsharo'a Ph. D. thesis, IIT, 2004





- New modular cavity for detailed systematic studies (SLAC, LBNL)
  - Modular design for easy assembly, inspection, parts replacement
  - Removable endplates (initially Cu; Be, other materials, treated surfaces)
  - Coupling iris moved to center ring and field reduced (*more realistic design for cooling channel*)
  - RF design validated by detailed simulation
  - Ports for instrumentation
  - Inspection setup under preparation
  - Fabrication close to completion
  - Expected delivery to MTA: FY14 Q2
- Incorporates all lessons learned

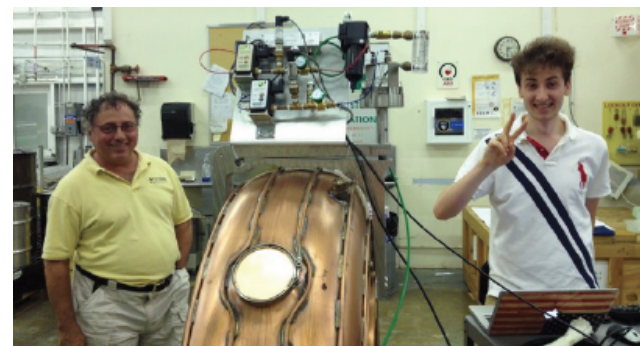
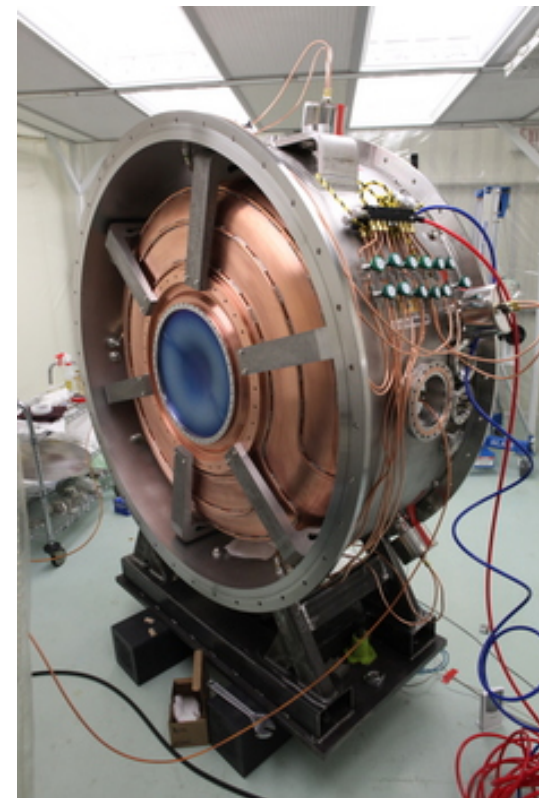




- MICE cavity in vacuum vessel for MTA test
- Components
  - 1<sup>st</sup> MICE cavity EP'ed at LBNL
  - Vacuum vessel built at Keller
  - Be windows to be reused
  - Actuators built at LBNL
  - Tuner forks built at FNAL
  - New coupler fabrication in progress at LBNL

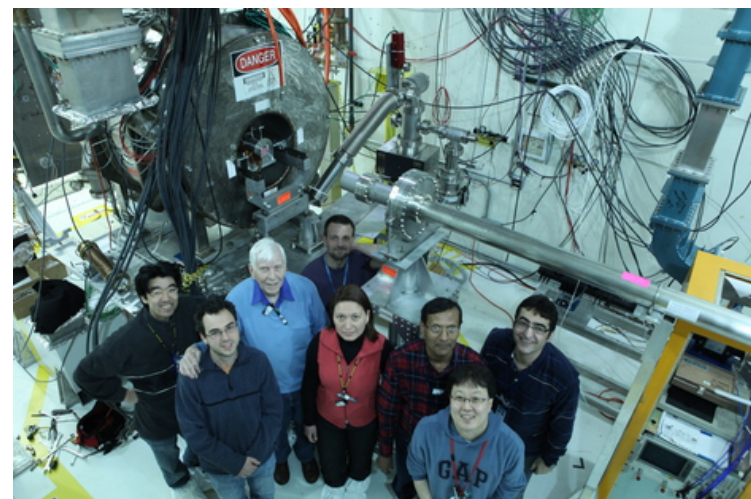


- Assembly/integration
  - Clean room prepared in Lab-6
  - Main assembly complete
  - Plan in place for handling and transport to MTA
  - Tuner system tested
  - Hall infrastructure
    - Services mostly in place
    - Overhead crane installation to start soon
  - Expect operation Spring 2014
    - depending on coupler delivery, hall infrastructure and RF source availability
  - beam test also under consideration
- Ultimately to be tested with the first Coupling Coil Magnet
  - Requires 6-month MTA shutdown (2015)





- HPRF previously tested at the MTA
  - Dense  $H_2$  gas buffers dark current while serving as ionization cooling medium
  - No B-field effect, 1 MV/m per atm  $H_2$
- 2 beam tests to evaluate response to high-intensity beam
  - Beam-induced plasma loads cavity
  - Mitigate with electronegative dopant
  - Wide range of parameters explored
  - Demonstrated operation with beam in 3T field
- Initial results published
  - Quantitative theory validated by measurement of energy loss in  $H_2/D_2$ +dopant
  - Dopants turn mobile ionization electrons into heavy ions, reducing RF losses by large factor
- Results extrapolate well to Neutrino Factory operation and a range of Muon Collider beam parameters
  - Plasma loading < beam loading
  - Bunch intensity limits being evaluated
- Also preparing for dielectric-loaded HPRF cavity test to enable smaller coils in HCC



PRL 111, 184802 (2013)

PHYSICAL REVIEW LETTERS

week ending  
1 NOVEMBER 2013

## Pressurized $H_2$ rf Cavities in Ionizing Beams and Magnetic Fields

M. Chung,<sup>1</sup> M. G. Collura,<sup>1</sup> G. Flanagan,<sup>2</sup> B. Freemire,<sup>3</sup> P. M. Hanlet,<sup>3</sup> M. R. Jana,<sup>1</sup> R. P. Johnson,<sup>2</sup> D. M. Kaplan,<sup>3</sup> M. Leonova,<sup>1</sup> A. Moretti,<sup>1</sup> M. Popovic,<sup>1</sup> T. Schwarz,<sup>1</sup> A. Tollestrup,<sup>1</sup> Y. Torun,<sup>3</sup> and K. Yonehara<sup>1</sup>

<sup>1</sup>Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA

<sup>2</sup>Muons, Inc., Batavia, Illinois 60134, USA

<sup>3</sup>Illinois Institute of Technology, Chicago, Illinois 60616, USA  
(Received 12 July 2013; published 29 October 2013)

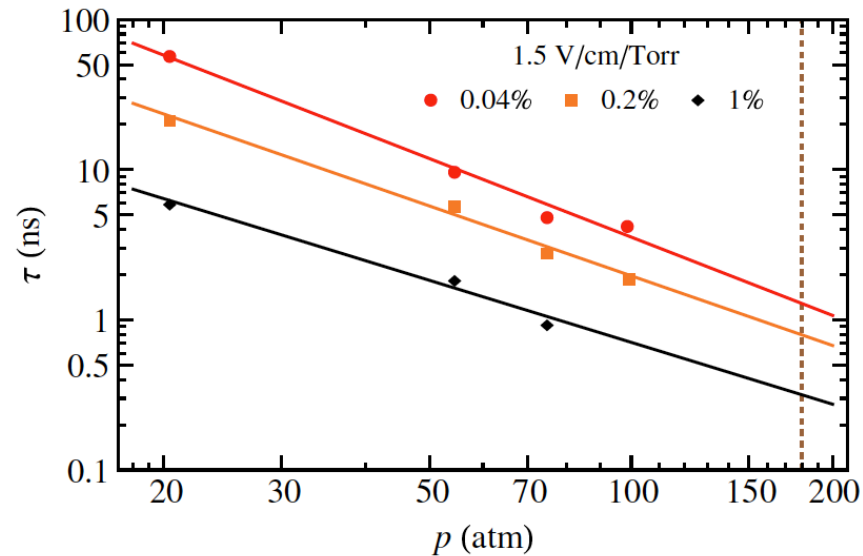
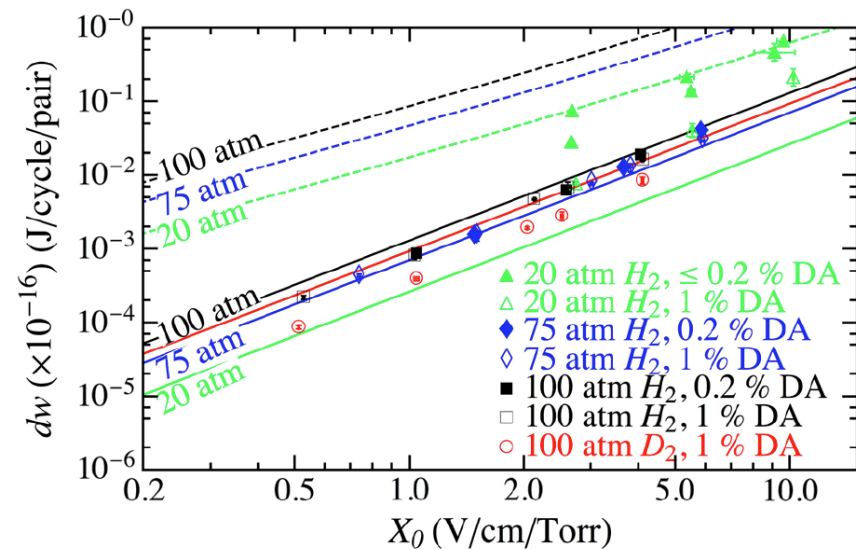
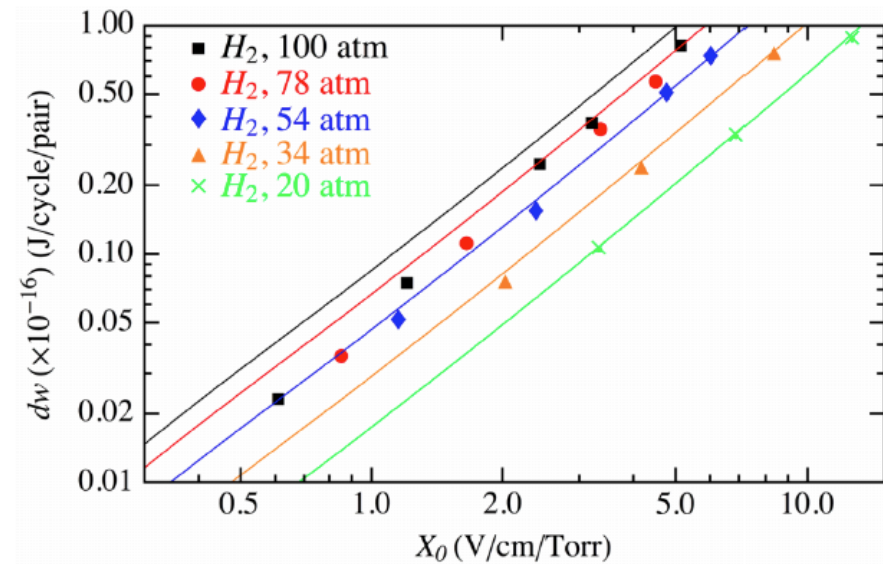
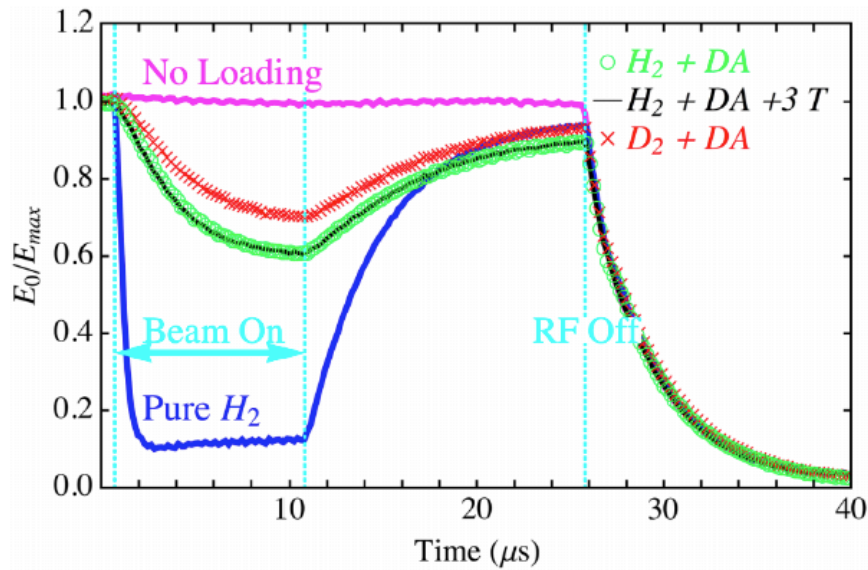
Measured (for  $H_2/D_2$ +dry air)

- Energy loss/e-ion pair/RF cycle
- e attachment time to oxygen
- Ion-ion recombination rates

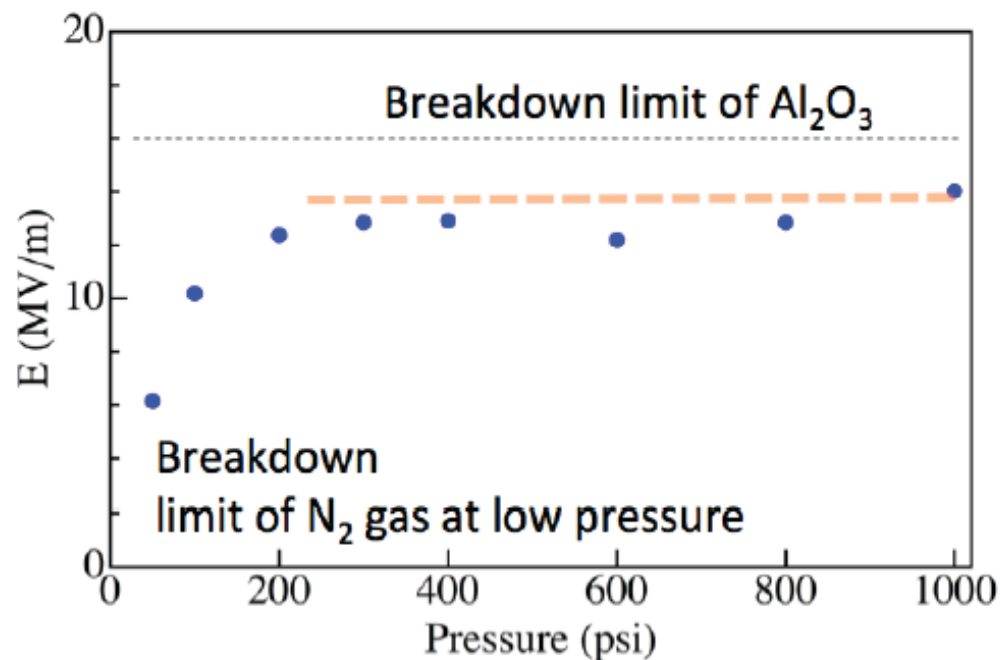
Analysis of rest of the data close to completion



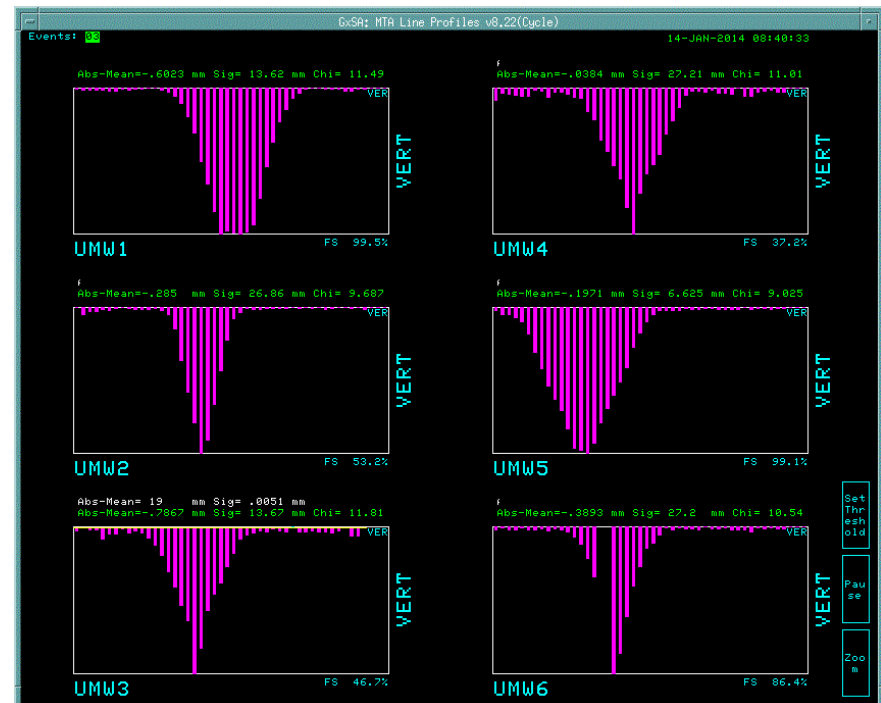
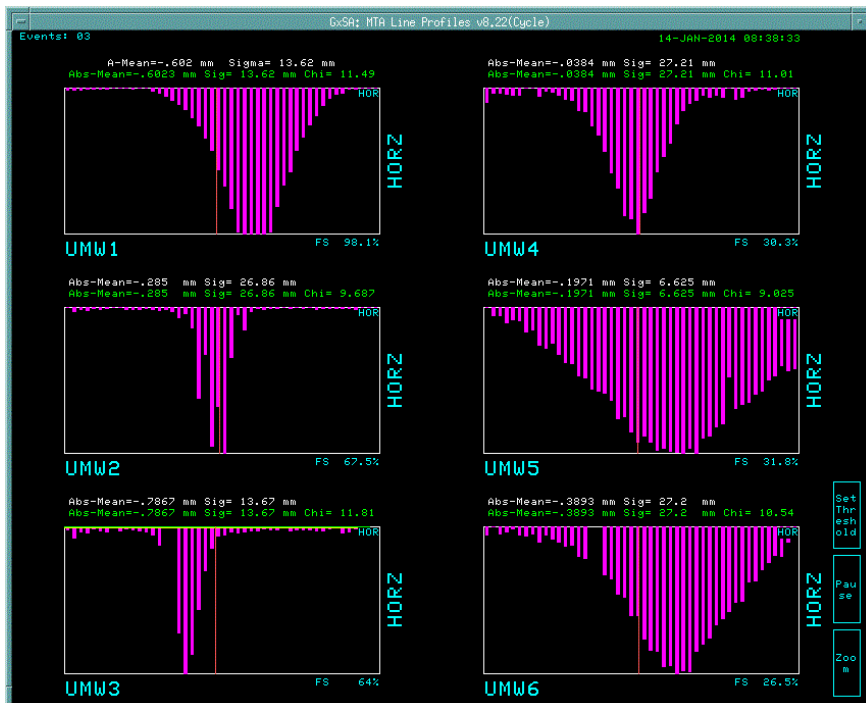
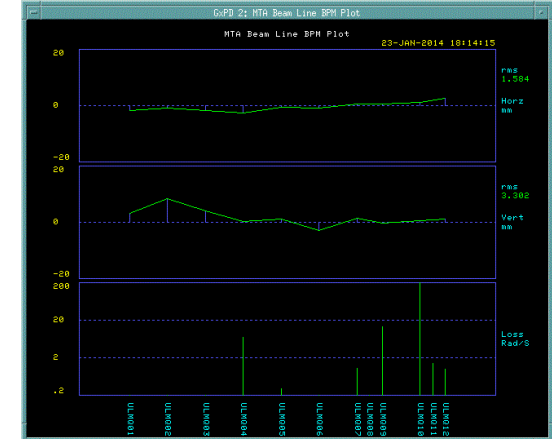
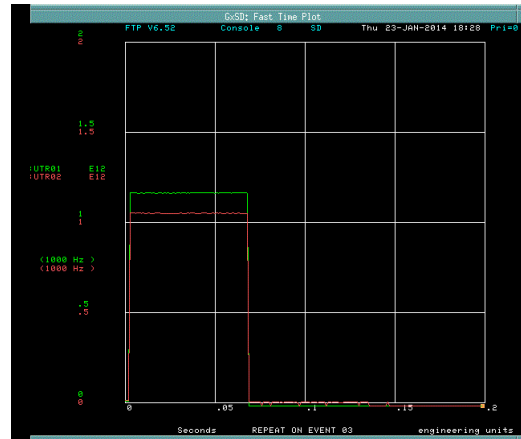
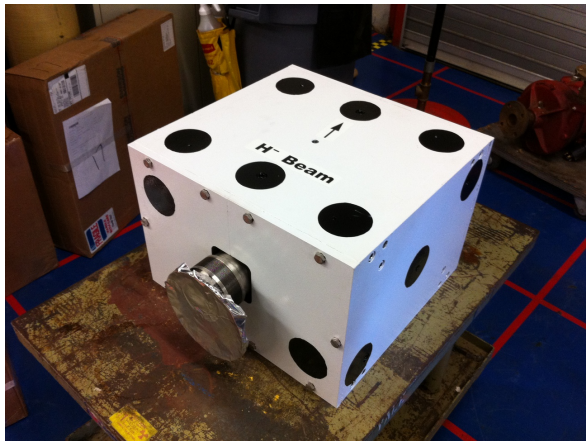
# Plasma Loading in HPRF Beam Test



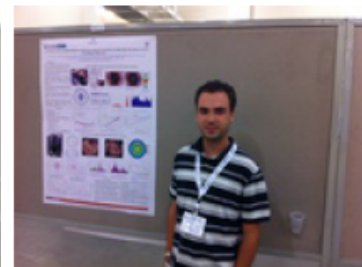
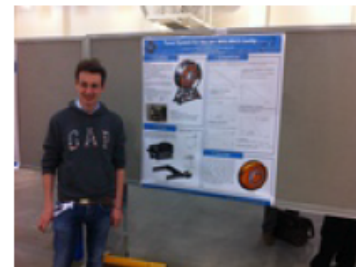
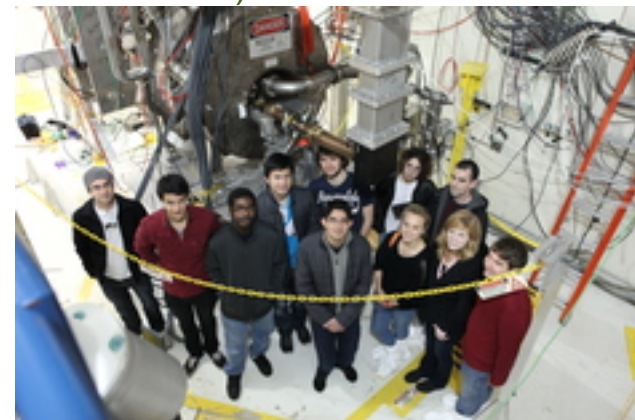
- Need to shrink transverse cavity size to reduce magnet apertures in HCC
- Proof-of-principle test: HPRF test cell + alumina
  - suppression of breakdown up to surface breakdown limit of material
- Other samples to be measured at low power
- High power test in MTA for promising candidates (suitable dielectric constant, low loss tangent)
- Beam test if successful
- Also looking at reentrant cavity design (Muons Inc)



# Beamline commissioning (M. Backfish, C. Johnstone)



- MTA program continued to support steady stream of students in FY13
  - Ben Freemire, IIT
    - Ph. D., May 2013 (HPRF beam test)
  - Peter Lane, IIT
    - Working toward Ph. D. (breakdown localization with acoustic sensors)
  - Luca Somaschini, INFN Pisa
    - About to receive M. Sc. (MICE cavity tuner system)
  - Jared Gaynier, Kettering U. (Fermilab coop)
    - Undergrad, major contribution to MICE SCM assy
  - Logan Rowe, John Sobolewski (coop)
    - Components for button pillbox and ASC
  - Lisa Nash (U. Chicago), Yiqing Ding (Purdue U.)
    - Grad, dielectric loaded HPRF design/testing
- Students first author on several IPAC13 and NAPAC13 abstracts





- [Pressurized H<sub>2</sub> rf Cavities in Ionizing Beams and Magnetic Fields](#), M. Chung *et al.*, Phys. Rev. Lett. 111, 184802 (2013)
- [High Pressure Gas-Filled RF Cavities for Use in a Muon Cooling Channel](#), B. Freemire *et al.*, NA-PAC13 proceedings
- [Investigation of Breakdown Induced Surface Damage on 805 MHz Pill Box Cavity Interior Surfaces](#), M. Jana *et al.*, NA-PAC13 proceedings
- [Multipacting Study for the RF Test of the MICE 201 MHz RF Cavity at Fermilab MTA](#), T. Luo *et al.*, NA-PAC13 proceedings
- [Modeling Vacuum Arcs in Linac Structures](#), J. Norem *et al.*, NA-PAC13 proceedings
- [Fermilab MuCool Test Area Cavity Conditioning Control Using LabVIEW](#), D. Peterson and Y. Torun, NA-PAC13 proceedings
- [Algorithms and Self-consistent Simulations of Beam-induced Plasma in Muon Cooling Devices](#), R. Samulyak *et al.*, NA-PAC13 proceedings
- [Tuner System Assembly and Tests for the 201-MHz MICE Cavity](#), L. Somaschini *et al.*, NA-PAC13 proceedings
- [Assembly and Testing of the First 201-MHz MICE Cavity at Fermilab](#), Y. Torun *et al.*, NA-PAC13 proceedings
- [Measurement of transmission efficiency for 400 MeV proton beam through collimator at Fermilab MuCool Test Area using Chromox-6 scintillation screen](#), M. R. Jana *et al.*, Rev. Sci. Instrum. 84, 063301 (2013)
- [Analysis of Breakdown Damage in an 805 MHz Pillbox Cavity for Muon Ionization Cooling R&D](#), D. Bowring *et al.*, IPAC13 proceedings
- [A Modular Cavity for Muon Ionization Cooling R&D](#), D. Bowring *et al.*, IPAC13 proceedings
- [Transient Beam Loading Effects in Gas-filled RF Cavities for a Muon Collider](#), M. Chung *et al.*, IPAC13 proceedings
- [Beam Induced Plasma Dynamics in a High Pressure Gas-Filled RF Test Cell for use in a Muon Cooling Channel](#), B. Freemire *et al.*, IPAC13 proceedings
- [Multipacting Simulation of the MICE 201 MHz RF Cavity](#), T. Luo *et al.*, IPAC13 proceedings
- [High Power Tests of Alumina in High Pressure RF Cavities for Muon Ionization Cooling Channel](#), L. Nash *et al.*, IPAC13 proceedings
- [The RF System for the MICE Experiment](#), K. Ronald *et al.*, IPAC13 proceedings
- [RF Cavity Spark Localization Using Acoustic Measurement](#), P. Snopok *et al.*, IPAC13 proceedings
- [Simulation of Beam-induced Gas Plasma in High Gradient RF Field for Muon Colliders](#), K. Yonehara *et al.*, IPAC13 proceedings
- [Summary of Dense Hydrogen Gas Filled RF Cavity Tests for Muon Acceleration](#), K. Yonehara *et al.*, IPAC13 proceedings

- Operating point for 805-MHz vacuum RF in 0-5T established, ASC program concluded
  - preparations mostly complete for next step (modular cavity)
  - test program to start this year
- MICE cavity assembly complete
  - Installation/commissioning soon
- Plasma loading for HPRF in beam evaluated
  - looks promising
- Proof-of-principle dielectric loading test complete
  - follow-up program in progress
- Facility/infrastructure
  - beamline upgrade commissioning in progress
  - overhead crane installation next
  - framework for external user experiments being put in place (detector prototype irradiation)